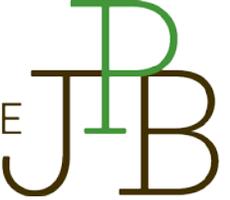


# TRANSFORMING AMERICA'S CITIES

*Actively managing sun and rain to improve health and comfort and slow global warming while saving several billion dollars*



Greg Kats and Keith Glassbrook, Capital E

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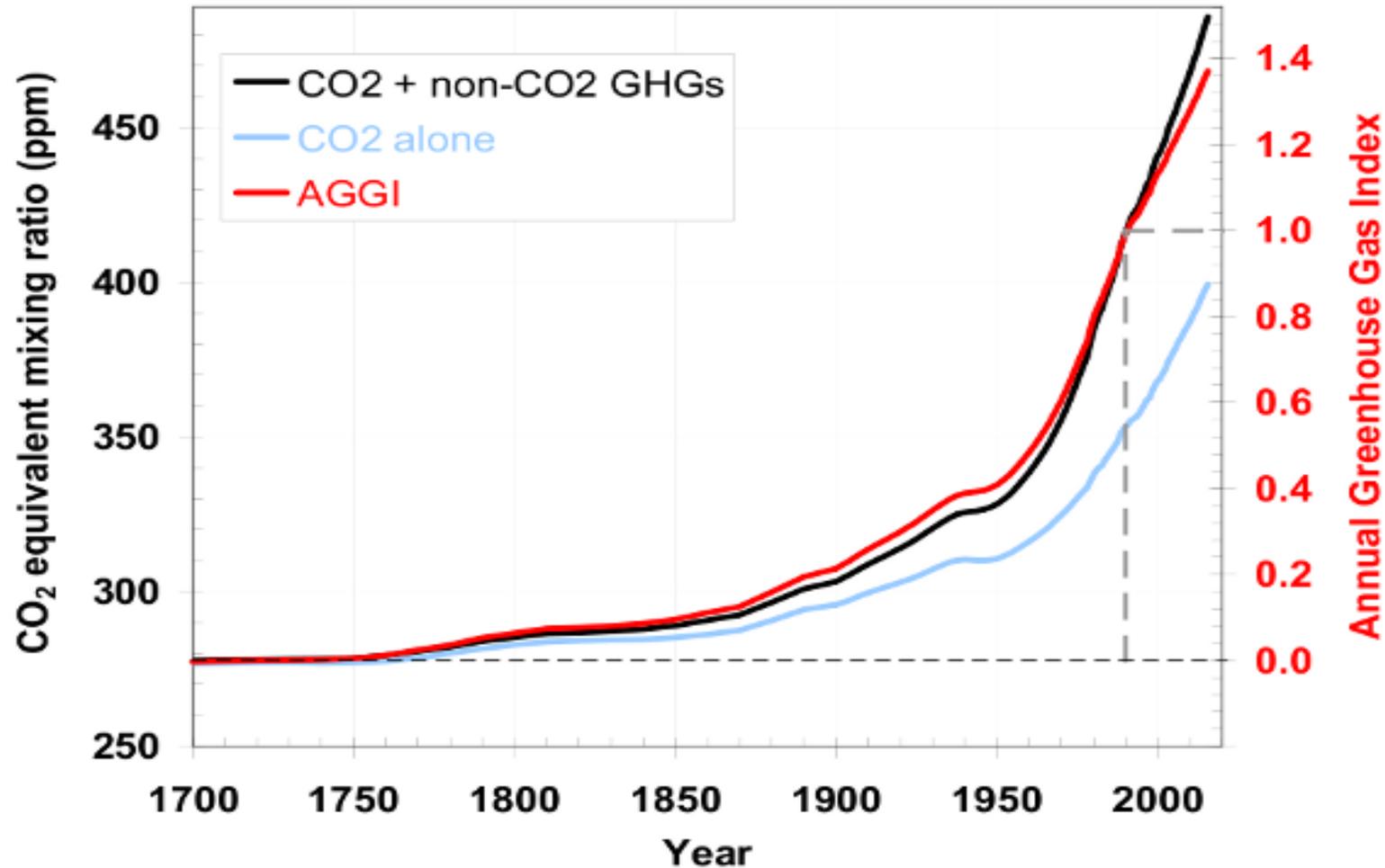
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# THE NOAA ANNUAL GREENHOUSE GAS INDEX

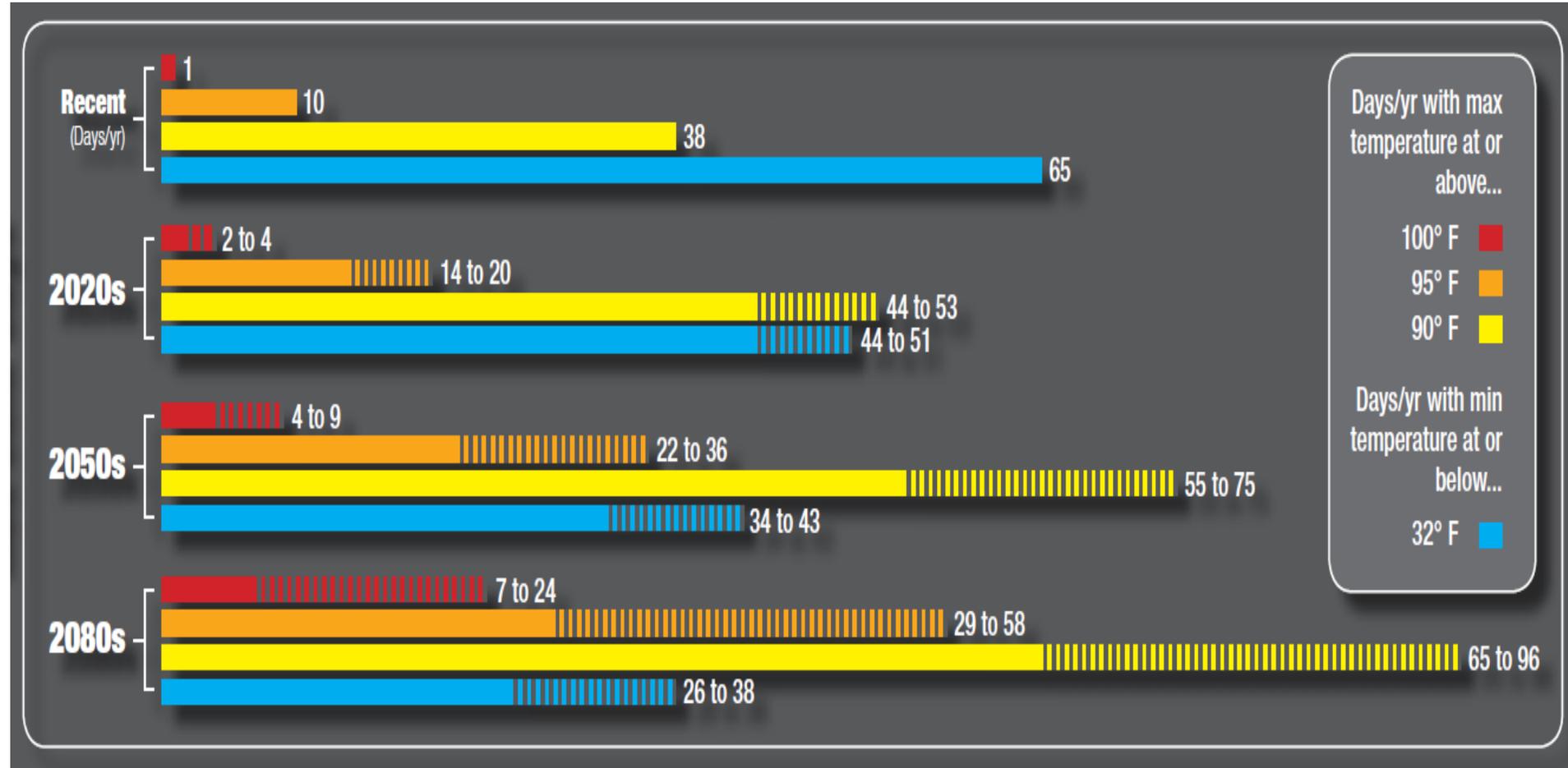
(Updated Spring 2016)

Global Warming/ climate change is accelerating, not slowing



# Washington DC temperature future under current climate change pathway

Source: NASA



# Examples of Smart Surface Technologies



Cool Roof



Green Roof



Reflective Pavement



Solar PV



Urban Trees

# Affordable Housing Smart Roofs (Phase 1)

- Builds on DC Smart Roof Mapping Initiative Capital E led for DC Department of General Services
- Funded by the JPB Foundation in 2013
- Goal: develop an affordable housing-focused model to quantify costs and benefits of various roof retrofit options
- Four cities and four technologies
  - Cities: Washington, DC, Baltimore, Philadelphia, and Los Angeles
  - Tech: Cool roofs, green roofs, solar PV, solar hot water

Present value over 40 years for each roof technology on the Washington, DC affordable housing property

COMPARISON	Cool compared to Conventional	Green compared to Conventional	Conventional w/ PV (PPA) compared to Conventional	Conventional w/ SHW (PPA) compared to Conventional
<b>COSTS</b>	<b>\$0.62</b>	<b>\$22.61</b>	<b>\$0.00</b>	<b>\$0.00</b>
<b>BENEFITS</b>	<b>\$4.60</b>	<b>\$60.89</b>	<b>\$69.17</b>	<b>\$124.68</b>
Energy	\$0.53	\$2.48	\$2.49	\$48.73
Stormwater	N/A	\$53.56	N/A	N/A
Health	\$4.01	\$4.03	\$52.10	\$27.88
Climate change	\$0.06	\$0.83	\$14.58	\$48.08
<b>NET TOTAL</b>	<b>\$3.98</b>	<b>\$38.28</b>	<b>\$69.17</b>	<b>\$124.68</b>

Roof Technology	Cool roof	Green roof	Rooftop PV	Solar hot water
Internal Rate of Return	77%	11%	N/A	N/A
Simple Payback (years)	2	11	N/A	N/A
Benefit-to-Cost Ratio	7.43	2.69	N/A	N/A
Net Present Value	\$3.98	\$38.28	\$69.17	\$124.68

# Smart Surfaces for Low Income City Areas (Phase 2)

- Funded by the JPB Foundation in 2015
- Goal: develop a low income region focused model quantifying costs and benefits of various roof and surface retrofit options
- Three cities and five solutions
  - Cities: Washington, DC, Baltimore, and Philadelphia
  - Solutions: Cool roofs, green roofs, solar PV, reflective pavements, urban trees

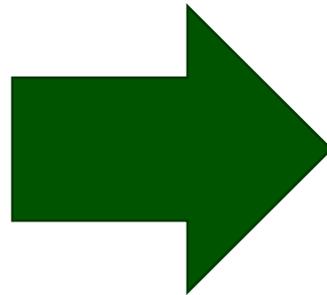
Present value over 40 years in North Philadelphia

SOLUTION	Cool Roofs	Green Roofs	PV (Direct Purchase)	PV (PPA)	Reflective Pavements	Urban Trees	TOTAL
<b>COSTS</b>	\$8,236,000	\$100,076,000	\$55,669,000	\$25,000	\$12,433,000	\$14,136,000	\$190,573,000
<b>BENEFITS</b>	\$70,797,000	\$115,154,000	\$92,676,000	\$95,456,000	\$26,789,000	\$31,113,000	\$431,981,000
<b>NPV</b>	\$62,561,000	\$15,079,000	\$37,007,000	\$95,431,000	\$14,356,000	\$16,977,000	\$241,408,000

SOLUTION	Cool Roofs	Green Roofs	PV (Direct Purchase)	PV (PPA)	Reflective Pavements	Urban Trees
<b>Benefit-to-Cost Ratio</b>	8.60	1.15	1.66	Very high	2.15	2.20

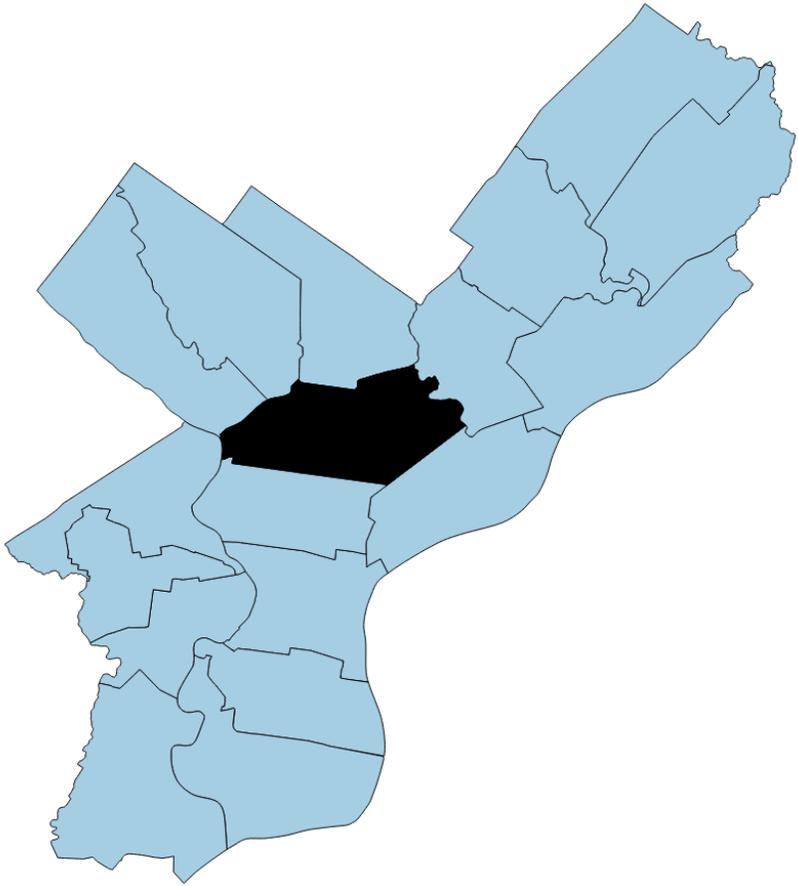
# Opportunity and Need (cont.)

- These temperature increases will put a severe strain on the city's infrastructure
  - Including increasing cooling energy use, reducing comfort, and increasing risk of heat-related deaths
- Changes in precipitation and sea level rise will put an enormous burden on the city's water infrastructure
  - Increasingly difficult for infrastructure to handle stormwater runoff and sewage overflow (Washington, DC and Philadelphia)
  - Increasingly important to keep water that fall on the city in the city (El Paso)



Demonstrates the need to prioritize urban cooling and stormwater managing measures in policy making and planning

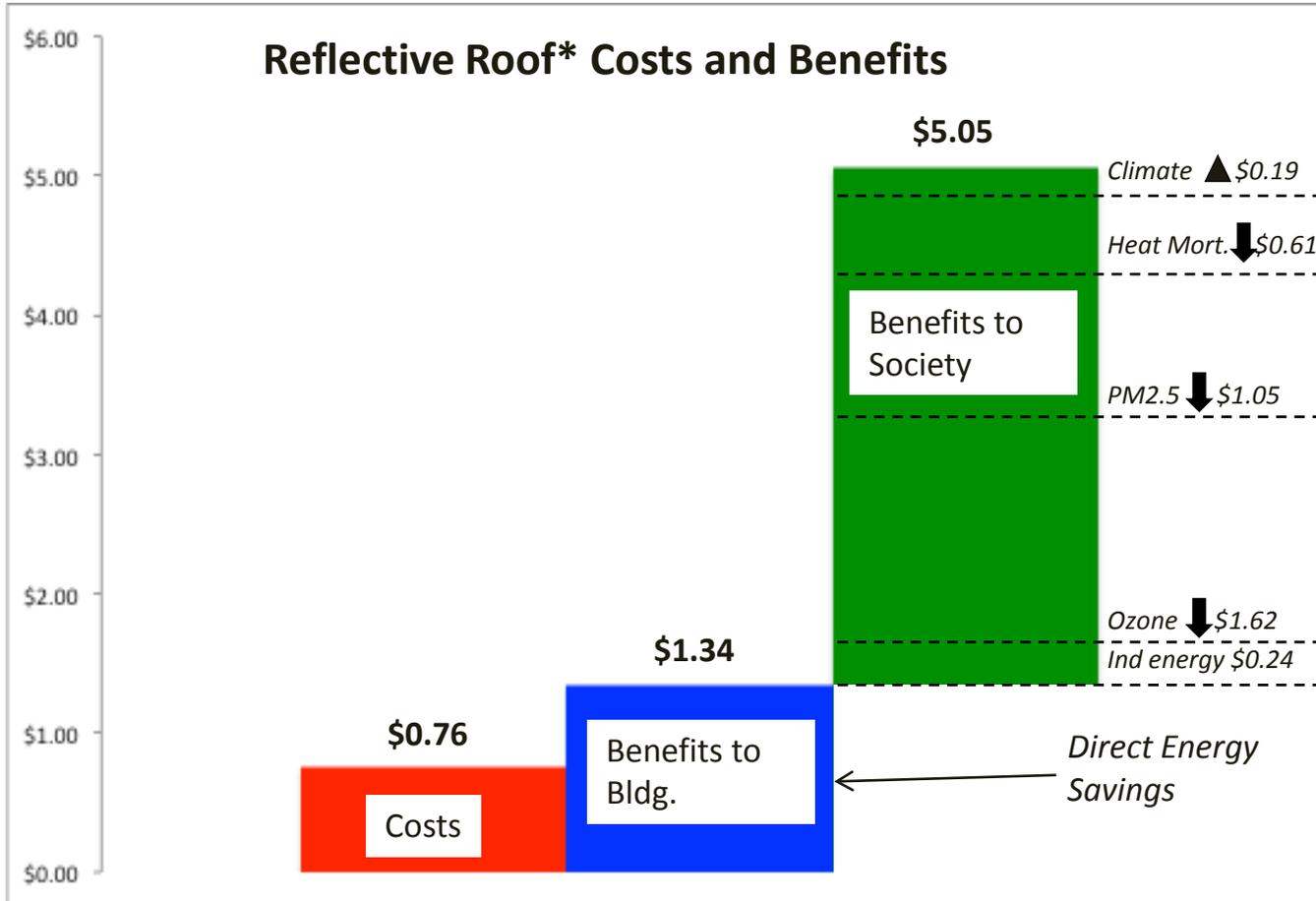
# Philadelphia and North Philadelphia



Characteristic	North Philadelphia (2035 District)	Philadelphia
Population (2014)	142,835	1,546,920
Income		
Median income	\$23,115	\$37,460
Percent of population below poverty line	45.2%	26.7%
Unemployment rate	24.8%	14.9%
Land use		
Area (square miles)	8.6	134.1
Building footprint (% region)	27.6%	18.7%
Paved area (roads, parking, sidewalks) (% region)	32.9%	26.6%
Tree canopy (% region)	10.1%	20.0%

# Cool Roof Benefits Valued

- Direct and indirect (urban heat island-related) energy savings
  - Reduced building energy use → lower energy expenditures
- Reduced ozone and fine particle (PM<sub>2.5</sub>) pollution
  - Reduced incidences of respiratory (e.g., worsened asthma, inflammation) and cardiovascular (e.g., heart disease) health problems and reduced mortality → lower healthcare expenditures
- Reduced heat-related mortality
  - Fewer deaths during the warm season that are related to the urban heat island → lower healthcare expenditures
- Global cooling and reduced greenhouse gas (GHG) emissions
  - Reduced climate change impacts → decreased economic damage due to climate change



\*0.15 to 0.65 reflectivity

Source: Capital-E

# Green Roof Benefits Valued

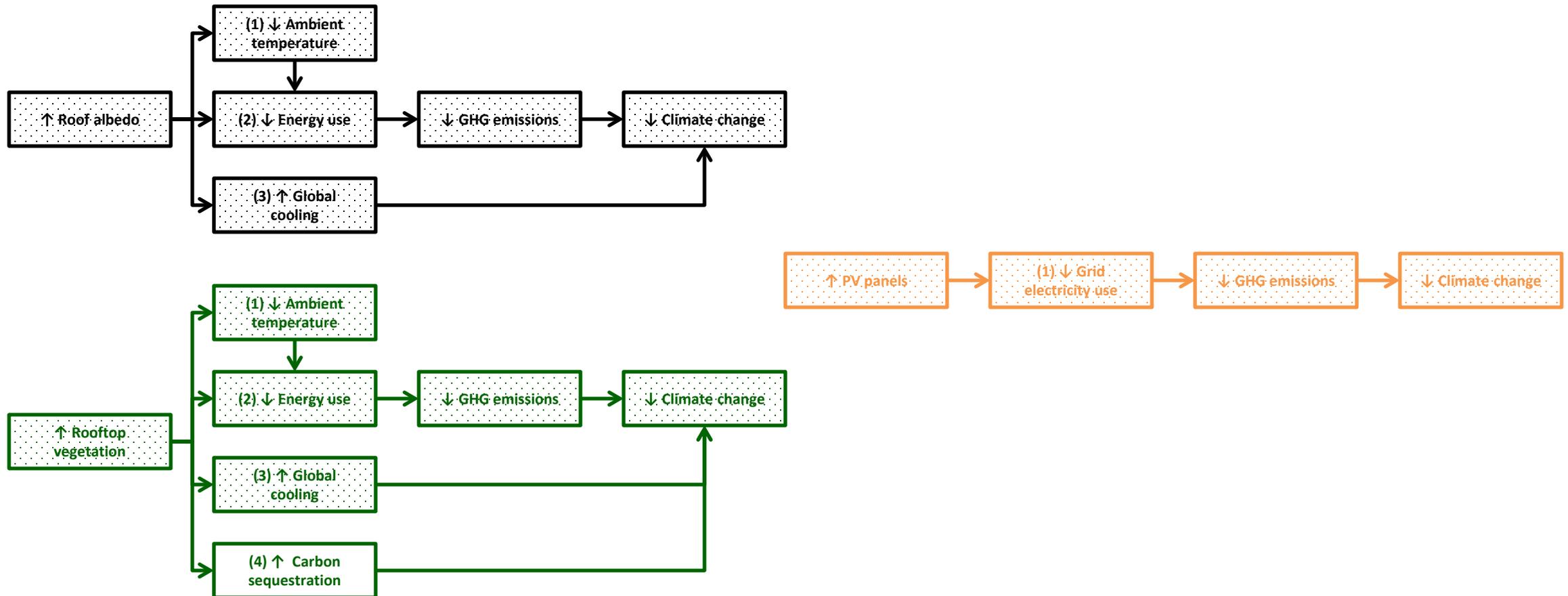
- Direct and indirect (urban heat island-related) energy savings
  - Reduced building energy use → lower energy expenditures
- Reduced ozone and fine particle (PM<sub>2.5</sub>) pollution
  - Reduced incidences of respiratory (e.g., worsened asthma, inflammation) and cardiovascular (e.g., heart disease) health problems and reduce mortality → lower healthcare expenditures
- Reduced heat-related mortality
  - Fewer deaths during the warm season that are related to the urban heat island → lower healthcare expenditures
- Global cooling and reduced GHG emissions
  - Reduced climate change impacts → decreased economic damage due to climate change
- Reduced stormwater runoff
  - Reduced stormwater runoff from the roof that contributes to combined sewer overflows and flash flooding and that harms local waterbodies and wildlife → reduced costs of stormwater management
- Increased employment
  - Increased labor intensity compared to conventional roofs → Increased income, increased tax revenue, and reduced welfare payments

# Reflective Pavements

- Indirect (urban heat island-related) energy savings
  - Reduced building energy use → lower energy costs
- Reduced ozone and fine particle (PM<sub>2.5</sub>) pollution
  - Reduced incidences of respiratory (e.g., worsened asthma, inflammation) and cardiovascular (e.g., heart disease) health problems and reduced mortality → lower healthcare expenditures
- Reduced heat-related mortality
  - Fewer deaths during the warm season that are related to the urban heat island → lower healthcare expenditures
- Global cooling and reduced greenhouse gas (GHG) emissions
  - Reduced climate change impacts → decreased economic damage due to climate change

# Climate Change Mitigation Pathways

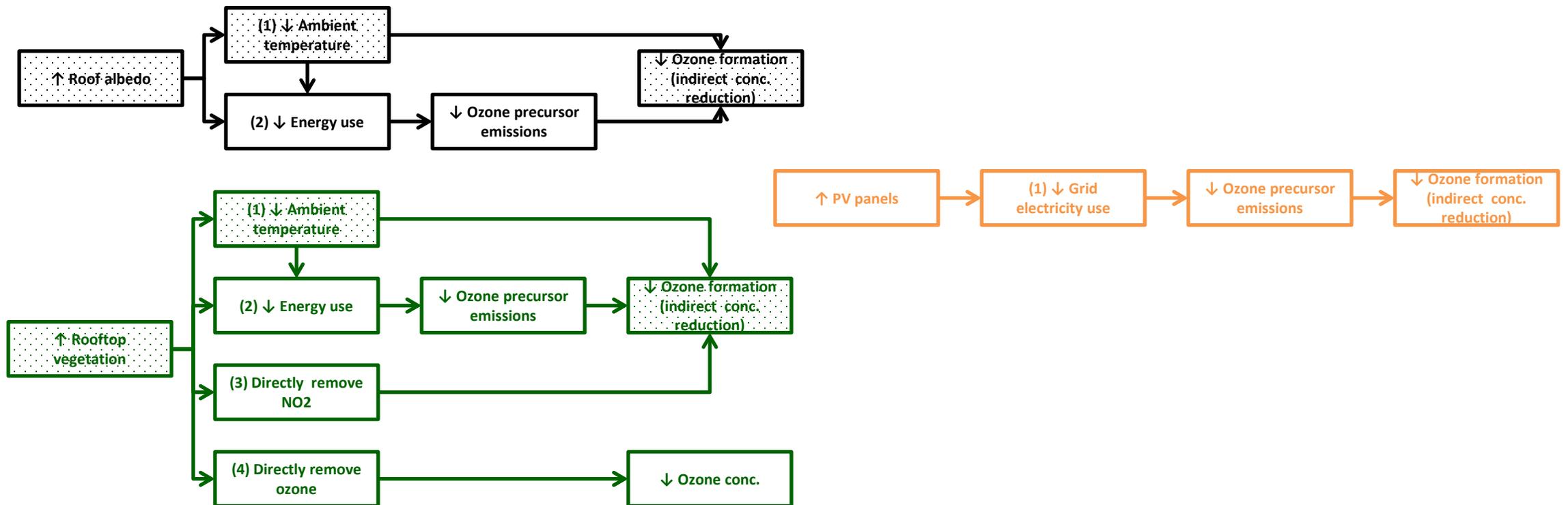
Note: Up arrows (↑) indicate an increase, and down arrows (↓) indicate a decrease; shaded boxes indicate pathways included in cost-benefit results



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# Ozone Reduction Pathways

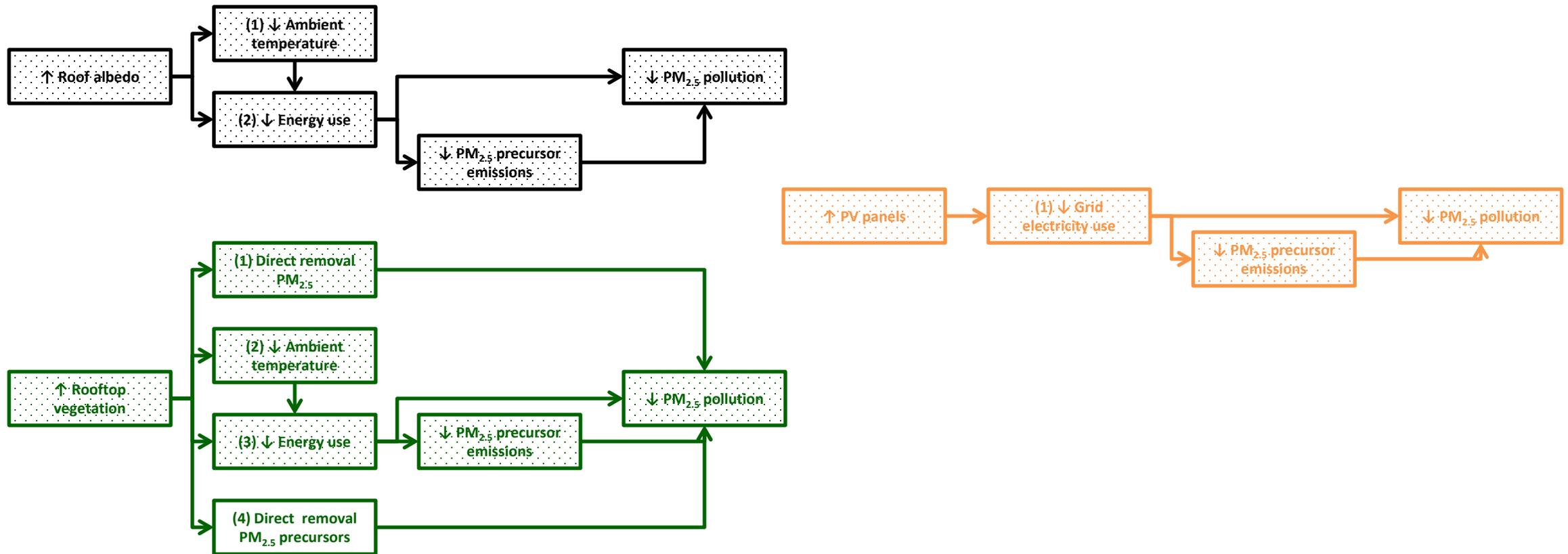
Note: Up arrows (↑) indicate an increase, and down arrows (↓) indicate a decrease; shaded boxes indicate pathways included in cost-benefit results



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# PM2.5 Reduction Pathways

Note: Up arrows (↑) indicate an increase, and down arrows (↓) indicate a decrease; shaded boxes indicate pathways included in cost-benefit results



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# Surface Coverage By End of 40-yr Analysis

Surface solution	Percent coverage by end of 40-year analysis
Cool roofs	50% of roofs
Green roofs	10% of roofs
Solar PV	50% of viable*
Reflective pavements	50% of pavements
Urban trees	Increase tree canopy by 10% absolute

\*Washington, DC = 530 MW; Philadelphia = 2.2 GW; El Paso = 870 MW

# Present Value of Building-level Benefits From Building Specific Installations in North Philadelphia (through 2056)

Results are additive

SOLUTION	Cool Roofs	Green Roofs	PV (Direct Purchase)	PV (PPA)	Reflective Pavements	Urban Trees	TOTAL
<b>COSTS</b>	<b>\$7,966,000</b>	<b>\$77,005,000</b>	<b>\$104,439,000</b>	<b>\$0</b>	<b>\$0</b>	<b>\$0</b>	<b>\$189,409,000</b>
<u>First cost</u>	\$5,873,000	\$52,987,000	\$70,066,000	--	--	--	\$128,925,000
<u>Operations and maintenance</u>	\$0	\$24,019,000	\$11,216,000	--	--	--	\$35,234,000
<u>Additional replacements</u>	\$2,093,000	--	\$23,157,000	--	--	--	\$25,250,000
<u>Employment training</u>	--	\$0	\$0	\$0	--	--	\$0
<b>BENEFITS</b>	<b>\$8,273,000</b>	<b>\$12,956,000</b>	<b>\$133,178,000</b>	<b>\$16,035,000</b>	<b>\$0</b>	<b>\$8,966,000</b>	<b>\$179,406,000</b>
<u>Energy</u>	\$8,273,000	\$5,442,000	\$107,407,000	\$16,035,000	\$0	\$1,455,000	\$138,609,000
<u>Financial incentives</u>	--	--	\$25,772,000	--	--	--	\$25,772,000
<u>Stormwater</u>	--	\$7,514,000	--	--	--	\$7,512,000	\$15,026,000
<u>Health</u>	\$0	\$0	\$0	\$0	\$0	\$0	\$0
<u>Climate change</u>	\$0	\$0	\$0	\$0	\$0	\$0	\$0
<u>Employment</u>	--	\$0	\$0	\$0	--	--	\$0
<b>NET PRESENT VALUE</b>	<b>\$307,000</b>	<b>-\$64,048,000</b>	<b>\$28,740,000</b>	<b>\$16,035,000</b>	<b>\$0</b>	<b>\$8,966,000</b>	<b>-\$10,002,000</b>

# Present Values of Cumulative Economic Impact in North Philadelphia (through 2056)

*Results are additive*

SOLUTION	Cool Roofs	Green Roofs	PV (Direct Purchase)	PV (PPA)	Reflective Pavements	Urban Trees	TOTAL
<b>COSTS</b>	<b>\$7,966,000</b>	<b>\$77,005,000</b>	<b>\$104,439,000</b>	<b>--</b>	<b>\$0</b>	<b>\$0</b>	<b>\$189,409,000</b>
<u>First cost</u>	\$5,873,000	\$52,987,000	\$70,066,000	--	--	--	\$128,925,000
<u>Operations and maintenance</u>	\$0	\$24,019,000	\$11,216,000	--	--	--	\$35,234,000
<u>Additional replacements</u>	\$2,093,000	--	\$23,157,000	--	--	--	\$25,250,000
<u>Employment training</u>	--	\$0	\$0	\$0	--	--	\$0
<b>BENEFITS</b>	<b>\$66,774,000</b>	<b>\$28,507,000</b>	<b>\$207,202,000</b>	<b>\$238,255,000</b>	<b>\$31,339,000</b>	<b>\$54,420,000</b>	<b>\$626,494,000</b>
<u>Energy</u>	\$10,317,000	\$5,974,000	\$107,407,000	\$16,035,000	\$894,000	\$2,534,000	\$143,158,000
<u>Financial incentives</u>	--	--	\$25,723,000	--	--	--	\$25,723,000
<u>Stormwater</u>	--	\$7,514,000	--	--	--	\$7,512,000	\$15,026,000
<u>Health</u>	\$29,608,000	\$8,412,000	\$35,053,000	\$105,159,000	\$15,366,000	\$38,226,000	\$231,822,000
<u>Climate change</u>	\$26,850,000	\$2,907,000	\$24,466,000	\$73,396,000	\$15,080,000	\$6,149,000	\$148,846,000
<u>Employment</u>	--	\$3,701,000	\$14,556,000	\$43,666,000	--	--	\$61,923,000
<b>NET PRESENT VALUE</b>	<b>\$58,809,000</b>	<b>-\$48,498,000</b>	<b>\$102,764,000</b>	<b>\$238,255,000</b>	<b>\$31,339,000</b>	<b>\$54,420,000</b>	<b>\$437,086,000</b>

# Present Value of City-wide Scenario Costs and Benefits in Philadelphia (through 2056)

*Results are additive*

SOLUTION	Cool Roofs	Green Roofs	PV (Direct Purchase)	PV (PPA)	Reflective Pavements	Urban Trees	TOTAL
<b>COSTS</b>	<b>\$93,527,000</b>	<b>\$698,646,000</b>	<b>\$955,786,000</b>	<b>\$2,156,000</b>	<b>\$118,086,000</b>	<b>\$515,852,000</b>	<b>\$2,384,050,000</b>
<u>First cost</u>	\$68,954,000	\$480,500,000	\$640,887,000	--	\$65,720,000	\$299,776,000	\$1,555,835,000
<u>Operations and maintenance</u>	\$0	\$217,807,000	\$102,260,000	--	--	\$170,500,000	\$490,566,000
<u>Additional replacements</u>	\$24,573,000	--	\$211,922,000	--	\$52,366,000	\$45,578,000	\$334,438,000
<u>Employment training</u>	\$0	\$340,000	\$719,000	\$2,156,000	--	--	\$3,214,000
<b>BENEFITS</b>	<b>\$692,110,000</b>	<b>\$270,707,000</b>	<b>\$1,856,379,000</b>	<b>\$2,089,614,000</b>	<b>\$357,433,000</b>	<b>\$692,420,000</b>	<b>\$5,958,661,000</b>
<u>Energy</u>	\$91,878,000	\$53,741,000	\$984,150,000	\$146,931,000	\$9,440,000	\$38,727,000	\$1,324,865,000
<u>Financial incentives</u>	--	--	\$224,667,000	--	--	--	\$224,667,000
<u>Stormwater</u>	--	\$68,140,000	--	--	--	\$117,264,000	\$185,403,000
<u>Health</u>	\$328,686,000	\$91,455,000	\$316,476,000	\$949,428,000	\$155,841,000	\$443,217,000	\$2,285,100,000
<u>Climate change</u>	\$271,547,000	\$26,984,000	\$220,886,000	\$662,657,000	\$192,154,000	\$93,213,000	\$1,467,438,000
<u>Employment</u>	--	\$30,390,000	\$110,201,000	\$330,601,000	--	--	\$471,190,000
<b>NET PRESENT VALUE</b>	<b>\$598,584,000</b>	<b>-\$427,938,000</b>	<b>\$900,593,000</b>	<b>\$2,087,459,000</b>	<b>\$239,348,000</b>	<b>\$176,568,000</b>	<b>\$3,574,611,000</b>

# Philadelphia Other Metrics (through 2056): Benefit-to-Cost Ratio and Employment

SOLUTION	Cool Roofs	Green Roofs – with ½ SRC value	PV (Direct Purchase)	PV (PPA)	Reflective Pavements	Urban Trees
<b>Benefit-to-Cost Ratio</b>	7.40	1.13	1.94	Very high	3.03	2.57

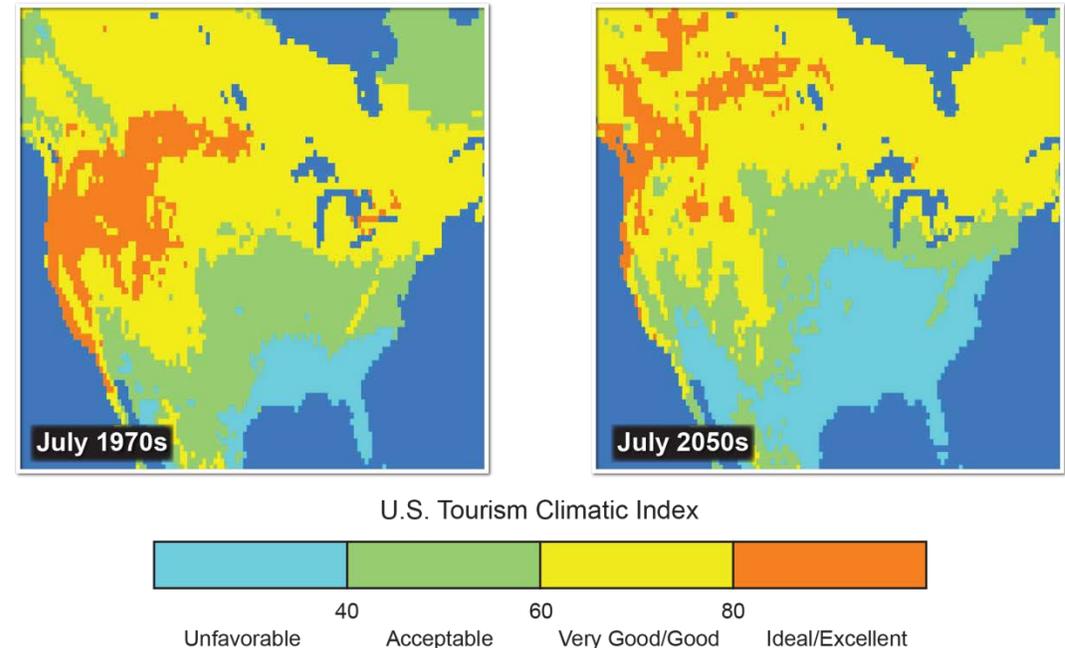
SOLUTION	Cool Roofs	Green Roofs – with ½ SRC value	PV (Direct Purchase)	PV (PPA)	Reflective Pavements	Urban Trees	TOTAL
<b>Job-years created for Philadelphia residents</b>	--	616	2,421	7,261	--	--	10,297
<b>Job-years created for Philadelphia residents per \$1,000,000 spent</b>	--	0.9	2.5	N/A	--	--	4.3

*\*\*Direct jobs only; we assume 50% of job created go to Philadelphia residents*

# Summertime Tourism

- Combination of higher average heat, greater frequency of extreme heat, and more air pollution will make the District, Philadelphia, and El Paso less attractive for tourists in the summer
- Smart surface solutions can help avoid potential tourism losses
- Net present value of this avoided loss over the 40-year analysis period would be:
  - \$3.1 billion in visitor spending in the District, including \$335 million in District tax revenue
  - Philadelphia
  - El Paso

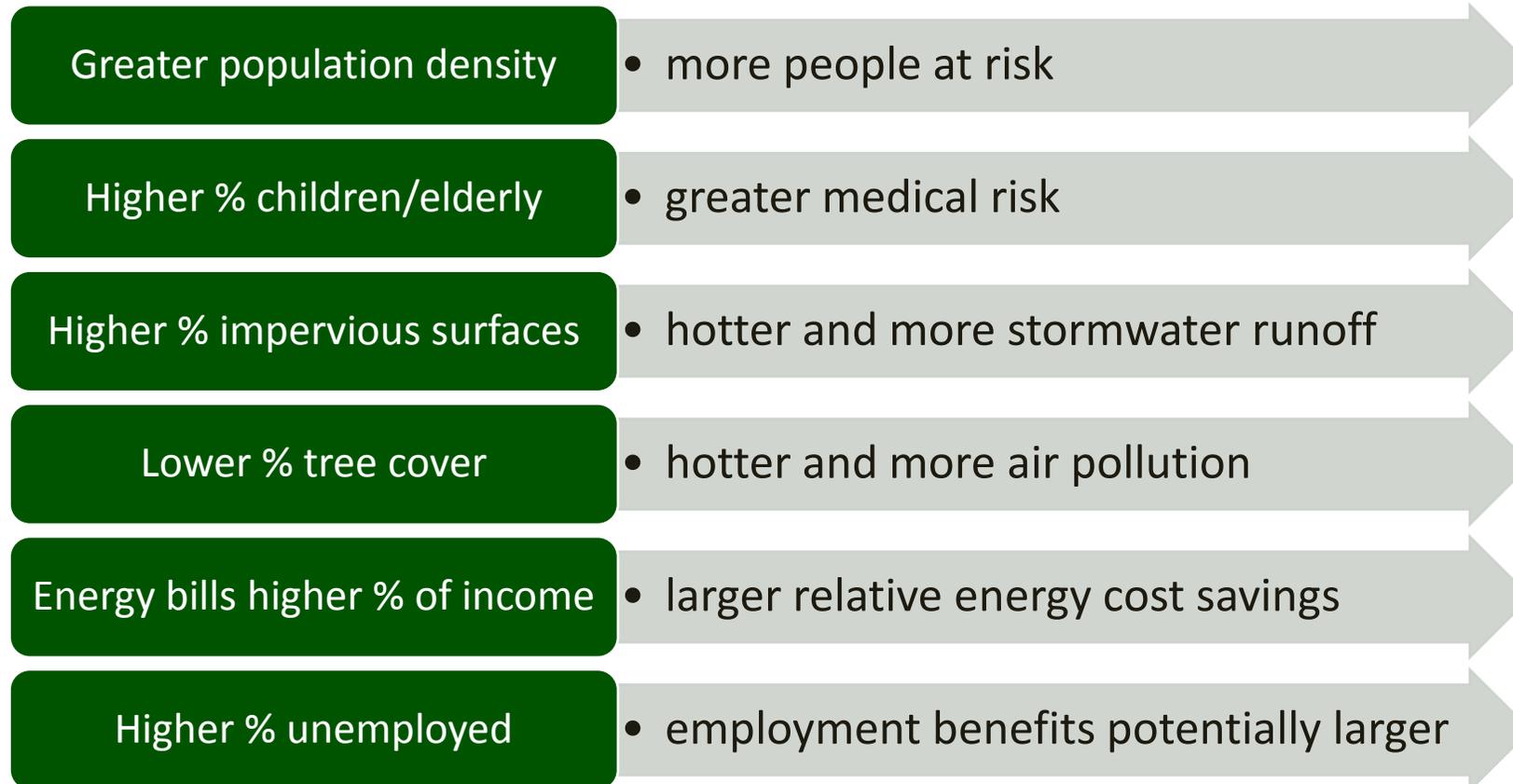
Climate Change Impacts on Summertime Tourism



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# Opportunity and Need (cont.)

*Low income areas typically have:*



# Conclusions

- Overall, smart surfaces solutions are cost-effective and generally provide large positive net benefits.
  - Overall, the net present value of deploying these solutions broadly is about
    - Washington, DC: \$1.8 billion.... \$5 billion if avoided tourism losses include
    - Philadelphia: \$3.6 billion.... \$9 billion if avoided tourism losses include
    - El Paso: \$540 million
- The payback times for these solutions vary a great deal
  - Cool roofs offer very fast payback, while several other solutions offer the largest net benefit
- We expect additional non-quantified benefits to each city and its residents are large and outweigh non-quantified costs
- Deployment of smart surface solutions at scale in low income areas can address systematic inequity in urban quality of life